C9.2 Crude oil

Q1 This question is about hydrocarbons.

(a) Most of the hydrocarbons in crude oil are alkanes.

(i) Large alkane molecules can be cracked to produce more useful molecules.

The equation shows the cracking of dodecane.

$$\underset{\text{dodecane}}{C_{12}H_{26}} \longrightarrow \underset{\text{butane}}{C_4H_{10}} + \underset{\text{hexene}}{C_6H_{12}} + \underset{\text{ethene}}{C_2H_4}$$

Give **two** conditions used to crack large alkane molecules.

1. _____

2. _____

(2)

(ii) The products hexene and ethene are alkenes.

Complete the sentence.

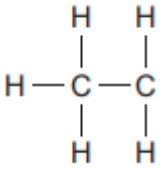
When alkenes react with bromine water the colour changes

from orange to _____ .

(1)

(iii) Butane (C_4H_{10}) is an alkane.

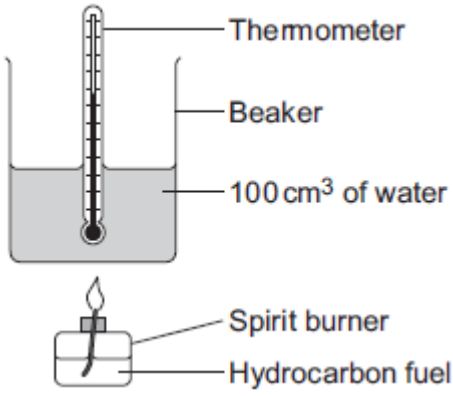
Complete the displayed structure of butane.



(1)

(b) A group of students investigated the energy released by the combustion of four hydrocarbon fuels.

The diagram below shows the apparatus used.



Each hydrocarbon fuel was burned for two minutes.

Table 1 shows the students' results.

Table 1

	After two minutes				
Name and formula of hydrocarbon fuel	**Mass of fuel used in g**	**Temperature increase of water in °C**	**Energy released by fuel in kJ**	**Energy released by 1.0 g of fuel in kJ**	**Relative amount of smoke in the flame**
Hexane, C_6H_{14}	0.81	40	16.80	20.74	very little smoke
Octane, C_8H_{18}	1.10	54	22.68	20.62	some smoke
Decane, $C_{10}H_{22}$	1.20	58	24.36		smoky
Dodecane, $C_{12}H_{26}$	1.41	67	28.14	19.96	very smoky

(i) Calculate the energy released by 1.0 g of decane in kJ.

Energy released = _____ kJ

(2)

(ii) Suggest **one** improvement to the apparatus, or the use of the apparatus, that would make the temperature increase of the water for each fuel more accurate.

Give a reason why this is an improvement.

(2)

(iii) The students noticed that the bottom of the beaker became covered in a black substance when burning these fuels.

Name this black substance.

Suggest why it is produced.

(2)

(iv) A student concluded that hexane is the best of the four fuels.

Give **two** reasons why the results in **Table 2** support this conclusion.

1. _____

_____

2. _____

_____

(2)

(c) **In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.**

Most car engines use petrol as a fuel.

- Petrol is produced from the fractional distillation of crude oil.
- Crude oil is a mixture of hydrocarbons.
- Sulfur is an impurity in crude oil.

Car engines could be developed to burn hydrogen as a fuel.

- Hydrogen is produced from natural gas.
- Natural gas is mainly methane.

Table 2 shows information about petrol and hydrogen.

Table 2

	Petrol	**Hydrogen**
State of fuel at room temperature	Liquid	Gas
Word equation for combustion of the fuel	petrol + oxygen ⟶ carbon dioxide + water	hydrogen + oxygen ⟶ water
Energy released from combustion of 1 g of the fuel	47 kJ	142 kJ

Describe the **advantages** and **disadvantages** of using hydrogen instead of petrol in car engines.

Use the information given and your knowledge and understanding to answer this question.

(6)

(Total 18 marks)

Q2. Crude oil is a fossil fuel.

(a) To make crude oil more useful it is separated into fractions.

Use the correct word from the box to complete each sentence.

boiling	**compound**	**decomposition**	**distillation**
	filtration	**mixture**	**molecule**

(i) Crude oil is a _____ of different substances.

(1)

(ii) The substances in crude oil have different

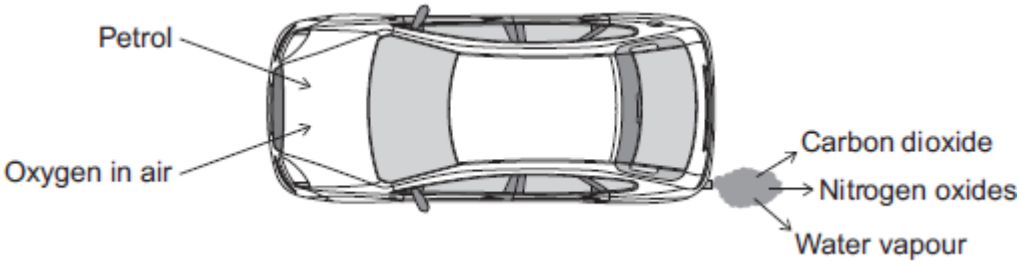
_____ points.

(1)

(iii) Crude oil is separated by fractional _____ .

(1)

(b) Petrol is one of the fractions produced from crude oil. Car engines use a mixture of petrol and air. The diagram shows some of the gases produced.



(i) What type of reaction happens to petrol in a car engine?

Tick (✓) **one** box.

combustion ☐

decomposition ☐

neutralisation ☐

(1)

(ii) Petrol contains octane (C_8H_{18}).

Complete the word equation for the reaction of octane with oxygen.

octane + _____ ⟶ _____ + _____

(2)

(iii) Cars use sulfur-free petrol as a fuel.

Describe why sulfur should be removed from petrol.

_____

_____

(2)

(c) Some fractions from crude oil contain large hydrocarbon molecules.

These molecules can be cracked to produce smaller, more useful molecules.

An equation for cracking decane is:

$C_{10}H_{22}$	⟶	C_3H_8	+	C_2H_4	+	C_5H_{10}
decane		propane		ethene		pentene

(i) Why is propane useful?

Tick (✓) **one** box.

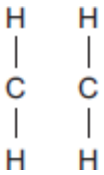
Propane is a polymer. ☐

Propane is an alloy. ☐

Propane is a fuel. ☐

(1)

(ii) Draw bonds to complete the displayed structure of ethene.



(1)

(iii) What is the colour change when bromine water reacts with ethene?

Tick (✓) **one** box.

Orange to colourless ☐

Orange to green ☐

Orange to red ☐

(1)

(iv) Complete the sentence.

Pentene is useful because many pentene molecules can join together to form _____ .

(1)

(Total 12 marks)

Higher Tier Questions

Q3.

This question is about cycloalkenes.

Cycloalkenes are ring-shaped hydrocarbon molecules containing a double carbon-carbon bond.

Cycloalkenes react in a similar way to alkenes.

(a) Describe a test for the double carbon-carbon bond in cycloalkene molecules.

Give the result of the test.

Test _____

Result _____

(2)

(b) The table below shows the name and formula of three cycloalkenes.

Name	**Formula**
Cyclobutene	C_4H_6
Cyclopentene	C_5H_8
Cyclohexene	C_6H_{10}

Determine the general formula for cycloalkenes.

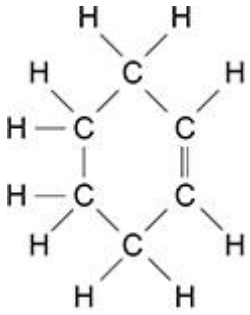
_____

General formula = _____

(1)

Figure 1 shows the displayed structural formula of cyclohexene, C_6H_{10}

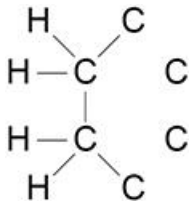
Figure 1



Chlorine reacts with cyclohexene to produce a compound with the formula $C_6H_{10}Cl_2$

(c) Complete **Figure 2** to show the displayed structural formula of $C_6H_{10}Cl_2$

Figure 2



(2)

(d) Calculate the percentage by mass of chlorine in a molecule of $C_6H_{10}Cl_2$

Relative atomic masses (A_r): H = 1 C = 12 Cl = 35.5

Percentage by mass = _____ %

(3) (Total 8 marks)

Q4. This question is about alkenes and alcohols.

Ethene is an alkene produced from large hydrocarbon molecules.

Large hydrocarbon molecules are obtained from crude oil by fractional distillation.

(a) Name the process used to produce ethene from large hydrocarbon molecules.

(1)

(b) Describe the conditions used to produce ethene from large hydrocarbon molecules.

(2)

(c) Ethanol can be produced from ethene and steam. The equation for the reaction is:

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$$

The forward reaction is exothermic. Explain how the conditions for this reaction should be chosen to produce ethanol as economically as possible.

(6)

(d) Ethanol can also be produced from sugar solution by adding yeast.

Name this process.

_____

(1)

(e) Butanol can be produced from sugar solution by adding bacteria.

Sugar solution is broken down in similar ways by bacteria and by yeast.

Suggest the reaction conditions needed to produce butanol from sugar solution by adding bacteria.

_____

_____

(2)

Ethanol and butanol can be used as fuels for cars.

(f) A car needs an average of 1.95 kJ of energy to travel 1 m

Ethanol has an energy content of 1300 kilojoules per mole (kJ/mol).

Calculate the number of moles of ethanol needed by the car to travel 200 km

_____

_____

Number of moles = _____ mol

(3)

(g) When butanol is burned in a car engine, complete combustion takes place.

Write a balanced equation for the complete combustion of butanol.

You do **not** need to include state symbols.

_____

(2)

(Total 17 marks)

Mark schemes

Q1.

(a) (i) high temperature

allow heating / hot / 250-900 °C

1

catalyst or steam

allow named catalyst eg zeolite, Al_2O_3, silica, ceramic

allow in the absence of air / oxygen

1

ignore any references to pressure

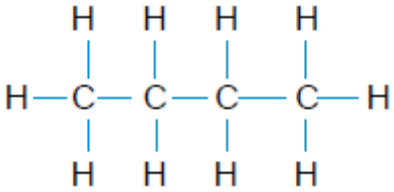
(ii) colourless

allow decolourised

ignore clear / discoloured

1

(iii)



1

(b) (i) 20.3(0) (kJ)

*if answer incorrect allow **1** mark for 24.36/1.2*

2

(ii) use a lid

allow insulate beaker or use draught shield

1

reduce energy / heat loss

ignore references to thermometer or repeats or distance of flame or loss of water vapour

allow stir (1) to distribute energy / heat (1)

allow use a metal can (1) as it's a better conductor (1)

1

(iii) carbon/soot

ignore tar, smoke

1

(produced by) incomplete combustion

allow from a limited supply of oxygen/air

1

(iv) hexane gives out the greatest energy (per 1.0 g)

ignore more energy

1

hexane produces the least smoke / carbon / soot

allow has the cleanest flame

ignore less smoke / carbon / soot

1

(c) Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response.

Examiners should also apply a 'best-fit' approach to the marking.

Level 3 (5 – 6 marks):
Descriptions of advantages **and** disadvantages that are linked to their own knowledge.

Level 2 (3 – 4 marks):
Descriptions of an advantage **and** a disadvantage with some use of their knowledge to add value.

Level 1 (1 – 2 marks):
Statements made from the information that indicate whether at least one statement is an advantage **or** a disadvantage
or a linked advantage or disadvantage

0 marks:
No relevant content

Examples of the added value statements and links made in the response could include:
Note that link words are in bold; links can be either way round.
Accept reverse arguments and ignore cost throughout.

Advantages of using hydrogen:
- Combustion only produces water **so** causes no pollution
- Combustion does not produce carbon dioxide **so** this does not contribute to global warming or climate change
- Combustion does not produce sulfur dioxide **so** this does not contribute to acid rain
- Incomplete combustion of petrol produces carbon monoxide **that is** toxic
- Incomplete combustion of petrol produces particulates **that** contribute to global dimming
- Petrol comes from a non-renewable resource **but** there are renewable/other methods of producing hydrogen
- Hydrogen releases more energy **so** less fuel needed or more efficient

Disadvantages of using hydrogen:
- Hydrogen is a gas **so** is difficult to store or transfer to vehicles
- Hydrogen gas is very flammable **so** leaks cause a greater risk of explosion
- Most hydrogen is produced from fossil fuels **which** are running out
- Cannot be used in existing car engines **so** modification / development or replacement is needed
- Lack of filling stations **so** difficult to refuel your vehicle

6

[18]

Q2.

(a) (i) mixture (of different substances)

1

(ii) boiling (points)

1

(iii) distillation

1

(b) (i) combustion

1

(ii) (reactant)

oxygen

allow correct formulae

1

(products)

products in any order

carbon dioxide

allow carbon or carbon monoxide

and

water

allow water vapour or steam or hydrogen oxide

1

(iii) (burning sulfur) produces sulfur dioxide / $S0_2$

allow it / sulfur reacts with oxygen ignore sulfur oxide

1

causes acid rain

1

(c) (i) propane is a fuel

1

(ii) double bond drawn between carbon atoms

do not allow any other bonds or symbols

1

(iii) orange to colourless

1

(iv) poly(pentene)

allow polymer(s)

1

[12]

Q3.

(a) (test)
(add) bromine (water)

1

(result)
(changes from) brown / orange to colourless

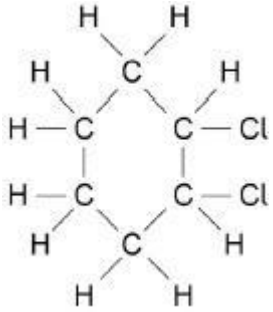
ignore clear

1

(b) C_nH_{2n-2}

1

(c)



*allow **1** mark for the structure of*
*1, 1-dichlorocyclohexane **or***
*1, 3-dichlorocyclohexane **or***
1, 4-dichlorocyclohexane

2

(d) (M_r ($C_6H_{10}Cl_2$) =) 153

1

(% chlorine=) $\frac{71}{153} \times 100$

allow correct use of an incorrectly calculated value of M_r

1

= 46.4 (%)

allow 46.405228758 (%) correctly rounded to at least 2 significant figures

1

[8]

Q4.

(a) (steam / catalytic) cracking

allow thermal decomposition

1

(b) high temperature

1

steam / catalyst

allow a temperature in the range 300 – 900 °C

1

(c) **Level 3:** Relevant points (reasons/causes) are identified, given in detail and logically linked to form a clear account.

5–6

Level 2: Relevant points (reasons/causes) are identified, and there are attempts at logical linking. The resulting account is not fully clear.

3–4

Level 1: Points are identified and stated simply, but their relevance is not clear and there is no attempt at logical linking.

1–2

No relevant content

0

Indicative content

Rate

- higher temperature gives higher rate
- because more frequent collisions
- higher pressure gives higher rate
- because more frequent collisions
- a catalyst can be used to give a higher rate
- because the activation energy is reduced

Yield

- higher temperature gives lower yield
- because the reaction is exothermic
- higher pressure gives higher yield
- because there are more molecules on left hand side

Other factors

- higher temperatures use more energy so costs increase
- higher pressures use more energy so costs increase
- higher pressures require stronger reaction vessels so costs increase

Compromise

- chosen temperature is a compromise between rate and yield
- chosen temperature is a compromise between rate and cost (of energy used)
- chosen pressure is a compromise between rate and cost (of energy used)
- chosen pressure is a compromise between yield and cost (of energy used)

(d) fermentation

allow ferment(ing)

1

(e) warm

allow a value in the range 25 °C to 45 °C

1

anaerobic (conditions)

allow without oxygen / air

1

(f) (conversion)

200 km = 200,000 m

1

(moles =) $\frac{200000 \times 1.95 \text{ (mol)}}{1300}$

allow correct use of incorrect / no conversion for distance

1

= 300 (mol)

1

(g) $C_4H_9OH + 6O_2 \rightarrow 4CO_2 + 5H_2O$

allow $C_4H_{10}O$ for C_4H_9OH

allow multiples

*allow **1** mark for*

$C_4H_9OH + O_2 \rightarrow CO_2 + H_2O$

with incorrect / no multipliers

ignore state symbols

2

[17]